# CHANGES IN SALINITY AND IN THE DISTRIBUTION OF MACROPHYTES, MACROBENTHOS AND FISH IN THE COORONG LAGOONS, SOUTH AUSTRALIA, FOLLOWING A PERIOD OF RIVER MURRAY FLOW

by M. C. GEDDES*

**Summary**

GEDDES, M. C. (1987) Changes in salinity and in the distribution of macrophytes, macrobenthos and fish in the Coorong Lagoons, South Australia, following a period of River Murray flow. *Trans. R. Soc. S. Aust.* 111(4), 173-181, 30 November, 1987.

This study was carried out to investigate the effects of the above average flow in the River Murray in 1983–84 on the salinity and the distribution of the biota in the Coorong Lagoons. Salinities fell only slightly in 1983, but by mid 1984 salinities had fallen significantly to be brackish (<30‰) in the North Lagoon and moderately hypersaline (55-70‰) in the South Lagoon. The biology and distribution of the biota showed changes that correlated with the freshening of the Coorong. *Ruppia megacarpa* flowered profusely in the North Lagoon in October 1983, and *R. tuberosa* grew extensively in the South Lagoon in 1984. The "estuarine-lagoonal" macroinvertebrate fauna in the North Lagoon extended its distribution to the southern extent of that lagoon; the species richness remained low with only two previously unrecorded species being collected. None of the typically estuarine-lagoonal macroinvertebrates occurred in the South Lagoon within the study period, although salinities were generally within their tolerance range in winter–spring 1984. Some freshwater fish occurred in the North Lagoon and *Aldrichetta forsteri* and *Acanthopagrus butcheri* (estuarine-marine species) moved into the South Lagoon for a brief period in spring 1984.

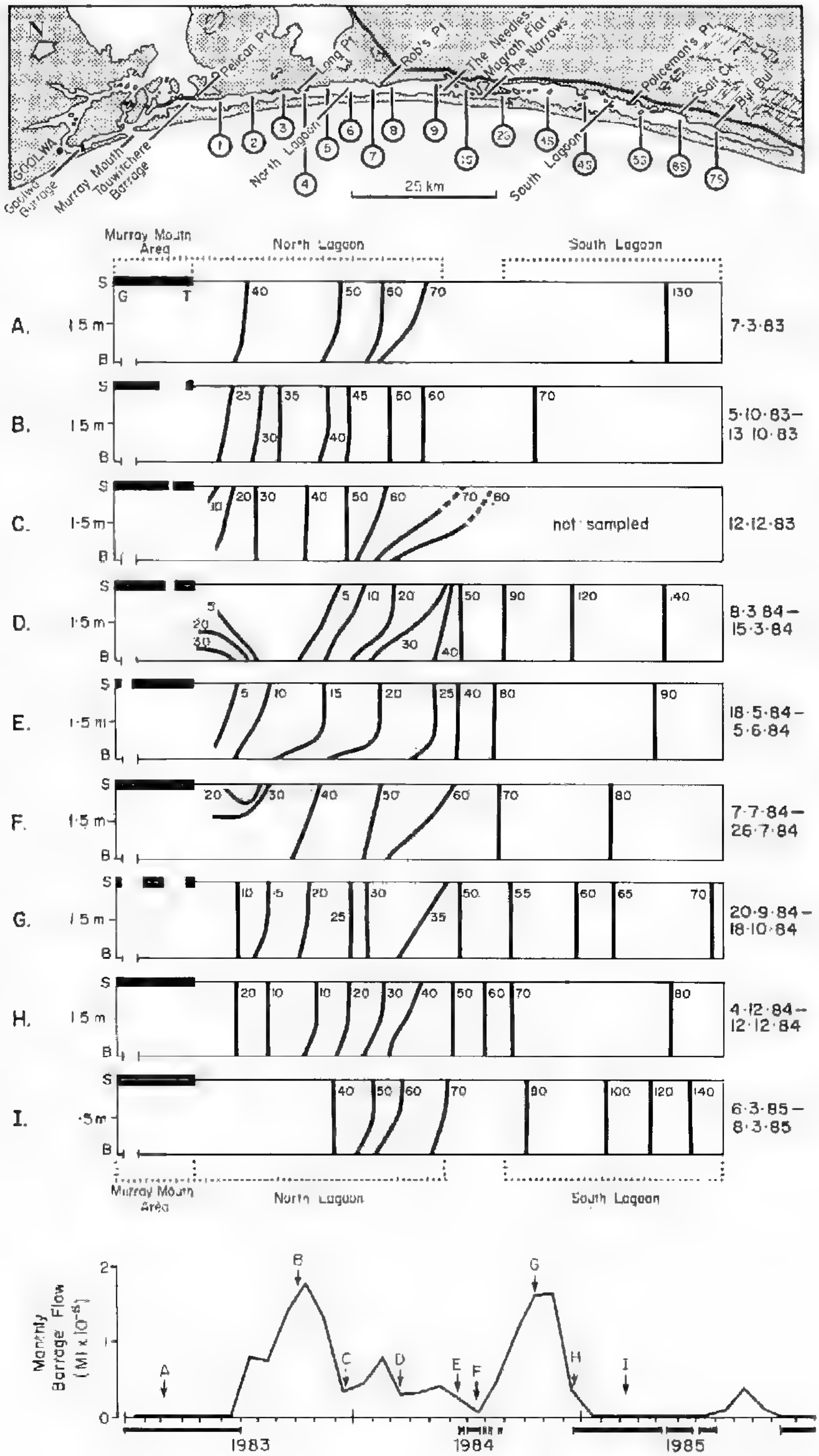
KEY WORDS: Coorong Lagoons, salinity, macroinvertebrates, fish, *Ruppia*.

## Introduction

The Coorong is an elongate coastal lagoon system which extends from the mouth of the River Murray some 100 km southeast along the South Australian coast (Fig. 1) and is characterized by a great range of salinity fluctuations (Geddes & Butler 1984). Exchange of water into the Coorong is from the Murray Mouth region at the northern end of the Coorong. Here either sea water from Encounter Bay or fresh water from the River Murray via Lake Alexandrina, can enter the Coorong. The formerly estuarine nature of the Murray Mouth region has been changed by River Murray regulation and by the erection of the River Murray Barrages, a system of low levees and gates (approximately 600 in all) across the outflow from Lake Alexandrina (Fig. 1). At times of low River Murray flow the water entering South Australia is sufficient only to meet abstraction requirements and evaporative losses and at these times the gates of the barrages are shut and the barrages separate fresh water retained in Lake Alexandrina from sea water in the Murray Mouth region. At periods of moderate or high River Murray flow, the gates on the barrages are opened to varying degrees and fresh water flows into the Murray Mouth region and the Coorong. Therefore the flow conditions in the River Murray determine the salinity of the water in the Murray Mouth region which is available for mixing into the Coorong and thus are a major factor controlling salinity in the Coorong Lagoons. The nature and distribution of the biota of the Coorong Lagoons is influenced by salinity (Geddes & Butler 1984; Kangas & Geddes 1984) and so River Murray flow is likely to influence the biology of the Coorong Lagoons.

A previous study of the Coorong (Geddes & Butler 1984; Kangas & Geddes 1984) was undertaken during a 16-month period (December 1981 to March 1983) of no outflow from the barrages. During this time the Coorong's salinities were marine to moderately hypermarine in the North Lagoon (35–50‰) and strongly hypersaline (80-110‰) in the South Lagoon. These conditions greatly restricted the distribution of the marine-derived estuarine-lagoonal fauna in the Coorong. In 1983 and 1984 there were moderate to high flows in the River Murray; the Murray flow year 1983–84 recorded a flow of 8.08 million Ml at Lock 1 compared with the long term median (1949-50 to 1982-83) of 5.96 million Ml. In mid 1983 there began a considerable outflow from the barrages so that the Coorong received diluting flows. This paper describes the changes in the salinity patterns in the Coorong from March 1983 until March 1985 and the effects of these changes on the distributions of macroinvertebrates, fish and macrophytes in the North and South Lagoons.

* Department of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, S. Aust. 5001.


GOOLWA
Goolwa Barrage
Murray Mouth
Tauwitchere Barrage
Pelican Pt
Long Pt
Rob's Pt
The Needles
Magrath Flat
The Narrows
Policeman's Pt
Salt Ck
Bul Bul
North Lagoon
South Lagoon
25 km
Murray Mouth Area
North Lagoon
South Lagoon
A.
B.
C.
D.
E.
F.
G.
H.
I.
7·3·83
5·10·83–13·10·83
12·12·83
not sampled
8·3·84–15·3·84
18·5·84–5·6·84
7·7·84–26·7·84
20·9·84–18·10·84
4·12·84–12·12·84
6·3·85–8·3·85
Monthly Barrage Flow (Ml x 10⁻⁶)
1983
1984
1985

## Methods

Eight visits, at approximately three monthly intervals, were made to the North and South Lagoons from October 1983–March 1985. The visits to the two lagoons were generally within two weeks of each other. In the North Lagoon physicochemical measurements and biological samples were taken from the nine stations of Geddes & Butler (1984). The methods for measuring conductivity at 25°C ($K_{25}$), salinity (measured as total dissolved solids, TDS), chlorophyll, turbidity, Secchi disc transparency (or Secchi depth) and $O_2$ concentration and for collecting benthic and littoral invertebrates, fish and macrophytes were as in Geddes & Butler (1984). In the South Lagoon $K_{25}$, TDS and turbidities were measured and benthic and littoral invertebrates were collected from seven stations (Fig. 1). The first of these stations (1S) was at Magrath Flat which is within the constricted region between the North and South Lagoons. The other six were in the South Lagoon from Vila de Yumpa to just north of Tea Tree Point. Additional information on the distribution of chironomids, macrophytes and fish in the South Lagoon were provided by Dr David Paton (Zoology Department, University of Adelaide) and Mr David Hall (Department of Fisheries, South Australia). Data on estimated outflows from the River Murray Barrages and on the patterns of opening and closing of the gates of the barrages were obtained from the Engineering and Water Supply Department, S. Aust.

## Results

### *Physicochemical*

Longitudinal and vertical patterns in salinity (TDS) in the North and South Lagoons, estimated outflows from the River Murray Barrages to the Murray Mouth and Coorong, and patterns of opening and closing of the barrages during 1983 and until mid 1985 are shown in Fig. 1. The barrages were closed from December 1981 (see Geddes & Butler 1984) until 1 July 1983. In March 1983 salinities were hypermarine throughout the Coorong ranging from 40‰–130‰ (Fig. 1A). By October 1983 (Fig. 1B), after 3 months of barrage outflow around 1 million Ml per month, salinities had fallen and ranged from 25 to 60‰ in the North Lagoon and were about 70‰ in the South Lagoon. By December (Fig. 1C), after continued good flows, salinities at the northern end of the North Lagoon had fallen slightly while those at the southern end of the North Lagoon had risen. There were considerable vertical salinity gradients at the northern and southern ends of the North Lagoon presumably caused by deeper level incursion of sea water and highly saline South Lagoon water respectively. A major freshening of the North Lagoon occurred between December 1983 and March 1984 (Fig. 1D) with the entire lagoon becoming brackish and the northern half having surface salinities below 5‰. There were sharp vertical salinity gradients as fresher water overlaid denser saline water. Outflows over this period were moderate (approx. 0.3–0.8 million Ml per month) and by March the barrage gates were mostly closed. In the South Lagoon there was a longitudinal salinity gradient from 90–140‰ presumably as a result of high evaporation at the shallow southern extremity and limited longitudinal mixing. By May–June (Fig. 1E), after a continued period of moderate flow (0.3–0.4 million Ml), an even longitudinal gradient from <5–25‰ had developed in the North Lagoon and there was a steep gradient between the two lagoons, although there had been some freshening of the South Lagoon. In June and July monthly outflows were low and sea water moved from the Murray Mouth into the North Lagoon. Furthermore, by July 26 there had been a considerable movement of saline water from the South Lagoon into the North Lagoon (Fig. 1F), presumably as a result of changes in the water levels in the lagoons. This is clearly shown in Fig. 2, where longitudinal salinity patterns show that salinities rose from 24‰ and 41‰ at Stations 9 and 1S on June 5 to 34‰ and 72‰ on June 14. This exchange between the lagoons broke down the steep salinity discontinuity that had existed between them. During August and September of 1984 (Fig. 1G) barrage outflow increased and the North Lagoon showed an even longitudinal salinity gradient from <10–30‰. Exchange from the North Lagoon and seasonal rainfall further freshened the South Lagoon. High outflows (>1.5 million Ml per month) were recorded in October and early November, but by early December all gates on the barrages were closed. This reduced flow allowed seawater to enter the Coorong so that on December 4 (Fig. 1H) the longitudinal salinity pattern in the North Lagoon showed a block of fresher (<10‰)

Fig. 1. Longitudinal and vertical patterns in salinity (TDS ‰) in the North and South Lagoons of the Coorong at 9 sampling times from March 1983 until March 1985 and estimated monthly barrage outflow from the River Murray. The sampling localities in the North Lagoon (1-9), in the constricted region between the lagoons (1S), and in the South Lagoon (2S–7S) are indicated. Closure of the barrages is indicated by the solid horizontal bars in the Murray Mouth region. The degree of opening of the main barrages at Goolwa (G) and Tauwitcherie (T) is indicated by the position and size of the breaks in the bars representing the barrages.

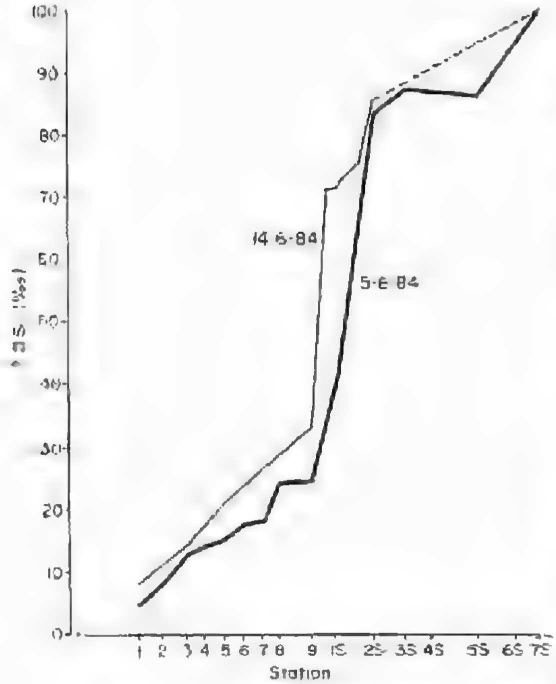



Fig. 2. Longitudinal patterns of surface salinity on 5 and 14 June 1984. Note the sharp gradient between Station 9 and Station 2S and the movement of saline water into the region 2S and 9 on June 14.

water half way down the lagoon bounded by saltier water to the northern and southern ends. All barrages remained closed until the final sampling date in March 1985 (Fig. 11) by which time salinities in the North Lagoon had risen above 35‰ and those in the South Lagoon to 140‰, so that the salinity pattern for the Coorong was very similar to that in March 1983.

Water temperature in the North Lagoon showed a seasonal pattern from a high of 24°C to a low of 11°C. On calm days a small vertical gradient existed, with surface temperatures up to 1.5°C higher than bottom temperatures. Secchi disc transparencies were high (up to 2.2 m) at the northerly stations in the period of no flow in March 1983 and then fell to around 0.5 m in October. Subsequently, they fluctuated generally between 0.5 and 1.5 m with no apparent pattern, probably reflecting local wind-driven turbulence. In the South Lagoon Secchi disc transparencies were lower varying between 0.3 and 0.7 m.

*Biological*

Chlorophyll *a* levels in the North Lagoon showed a longitudinal increase from Station 1 to 9 in March 1983. Diatoms, along with flagellates at Stations 7 and 9, were the dominant phytoplankters. During the flow period from mid 1983 until late 1984 chlorophyll levels fluctuated usually between 5 and 30 mg $m^{-3}$ but higher levels were recorded at Stations 1 and 3 when *Planktonema lauterbornei* was the dominant phytoplankter (presumably a wash-out from Lake Alexandrina where it is usually abundant (Geddes 1984)). By March 1985 chlorophyll levels were low at Stations 1 and 3, and high at Stations 7 and 9 where flagellates bloomed.

During 1983 and 1984 *Ruppia megacarpa* continued to be the dominant macrophyte in the North Lagoon with *Lepilaena cylindricarpa* also common and *Zostera muelleri* common at the more northerly stations. The *Ruppia* and *Lepilaena* beds were vigorous, extensive and flowering profusely in October 1983 along the length of the North Lagoon, especially from Station 5 southwards. They remained extensive until June 1984 and then died back. They became extensive and vigorous again by December 1984 but no flowering was observed in October or December 1984.

In the South Lagoon *Ruppia tuberosa* was the dominant macrophyte with *Lamprothamnion* sometimes common. Over the period October 1983 until July 1984 small specimens of *Ruppia* were observed in restricted areas. By September 1984 extensive beds of *Ruppia* occurred throughout the South Lagoon. These were probably produced from seeds that germinated in the freshening water (D. Paton pers. comm.). In December the northern and middle areas of the South Lagoon were fringed with extensive beds of *Ruppia* growing thickly in the shallows and flowering profusely. *Ruppia* died back during summer as water levels dropped and salinity rose. By April 1985 *Ruppia* was recorded only in the northern half of the Lagoon to Station 6S.

The macroinvertebrates and fish collected in the North Lagoon are listed in Table 1. Most species were collected on most occasions at Stations 1 to 5 where salinities usually ranged from 5–45‰, although some species including the polychaete *Australonereis ehlersi*, the gastropod *Salinator fragilis* and the bivalve *Notospisula trigonella*, were much less common than in the earlier study (Geddes & Butler 1984). In March 1984, when salinities fell to 2‰ at Stations 1 and 3 and 5‰ at Station 5, the polychaetes *Ceratonereis aequisetis* (formerly *C. pseudoerythraensis*), *Nephtys australiensis* and *Capitella capitata* were not collected from Station 1 although *C. aequisetis* was present at Station 3 and all three species were present at Station 5. Numerical dominant species that remained in high abundance in the littoral area during the estuarine phase in the North Lagoon were the amphipods *Melita zeylanica*, *Paracorophium* and *Megamphopus*, the

TABLE 1. *Macroinvertebrates and fish collected in hand net and benthic grab samples from the North Lagoon of the Coorong from October 1983 until March 1985.* (Those marked * were not recorded when similar samples were taken in 1982 (Geddes & Butler 1984).)

| | | |
|---|---|---|
| Fish | | *Arenigobius bifrenatus* (Kner) |
| | | *Pseudogobius olorum* (Sauvage) |
| | | *Atherinosoma microstoma* (Günther) |
| | | * *Philypnodon grandiceps* (Krefft) |
| | | * *Pseudaphritis urvilli* (Valenciennes) |
| | | * *Nematalosa erebi* (Günther) |
| Crustaceans | Decapods | *Macrobrachium intermedium* (Stimpson) |
| | Amphipods | *Melita zeylanica* Stebbing |
| | | *Paracorophium* cf. *excavatum* |
| | | [1] *Megamphopus/Podoceropsis/Gammaropsis* |
| | Ostracod | *Osticythere reticulata* Hartmann |
| Polychaetes | | [2] *Ceratonereis aequisetis* (Augener) |
| | | *Nephtys australiensis* (Fauchald) |
| | | *Australonereis ehlersi* (Augener) |
| | | * *Prionospio cirrifera* (Wiren) |
| | | *Ficopomatus enigmaticus* (Fauvel) |
| | | *Boccardia chilensis* Blake & Woodwick |
| | | *Capitella capitata* (Fabricius) |
| | | *Capitellides* spp. |
| | | Fabriciinae |
| | | * Questidae |
| Gastropods | | *Hydrobia buccinoides* (Quoy & Gaimard) |
| | | *Salinator fragilis* (Lamarck) |
| | | * *Tatea rufilabris* (Adams) |
| Bivalves | | *Notospisula trigonella* (Lamarck) |
| | | *Arthritica semen* (Menke) |
| | | *Soletellina donacioides* Reeve |
| Insects | Chironomid | *Tanytarsus barbitarsis* Freeman |
| | Ephydrid | *Ephydrella* sp. |

[1] This population was identified as *Megamphopus* sp. in Geddes & Butler (1984) and Kangas & Geddes (1984), but is more properly assigned to this multi-genus group, which is in need of revision (J. L. Barnard pers. comm.). *Megamphopus* sp. is used elsewhere in this paper for brevity.

[2] This population was identified as *C. pseudoerythraensis* Hutchings in Geddes & Butler (1984), but has been synonymized with *C. aequisetis* (Augener) (Hutchings & Glassby 1985).

polychaetes *Ceratonereis aequisetis* and *Ficopomatus enigmaticus*, and the gastropod *Hydrobia buccinoides*. The dominants in the benthic samples were *Capitella capitata* and *Paracorophium* with the bivalves *Notospisula trigonella* and *Arthritica semen* and the polychaetes *Nephtys australiensis* and *Prionospio cirrifera* common.

At Stations 7 and 9 high salinities (54–74‰) in March 1983 restricted the fauna so that only *Capitella capitata*, dipterans and the hardyhead *Atherinosoma microstoma* occurred at Station 9, and these plus *Salinator fragilis* and *Hydrobia buccinoides* at Station 7 (Fig. 3). By December 1983 after salinities at Station 7 had fallen below 50‰ in October, *Paracorophium*, *Megamphopus* and *Capitellides* were present and this last was also collected from Station 9. When salinities dropped sharply in March 1984 *Ficopomatus enigmaticus*, the fabriciine polychaetes, *Arthritica semen* and *Pseudogobius olorum* were collected from Station 7, and then *Melita zeylanica*, *Ceratonereis aequisetis* and *Notospisula trigonella* appeared in June and *Prionospio cirrifera*, *Macrobrachium intermedium* and *Tatea rufilabris* appeared later. Thus by October 1984 almost all of the common estuarine-lagoonal species that occur in the Coorong had colonized Station 7. The same pattern occurred at Station 9 except that colonization was generally later and *Melita zeylanica*, *Tatea rufilabris* and *Macrobrachium intermedium* were not found. When salinities rose from December 1984 to March 1985 many species disappeared from Stations 7 and 9 (Fig. 3).

None of the common estuarine-lagoonal invertebrates of the North Lagoon were collected from the South Lagoon. Here, the macroinvertebrate fauna was very restricted, comprising only the chironomid *Tanytarsus barbitarsis*, the ephydrid *Ephydrella*, other dipteran larvae, the isopod *Haloniscus searlei* and ostracods including *Diacypris compacta*.

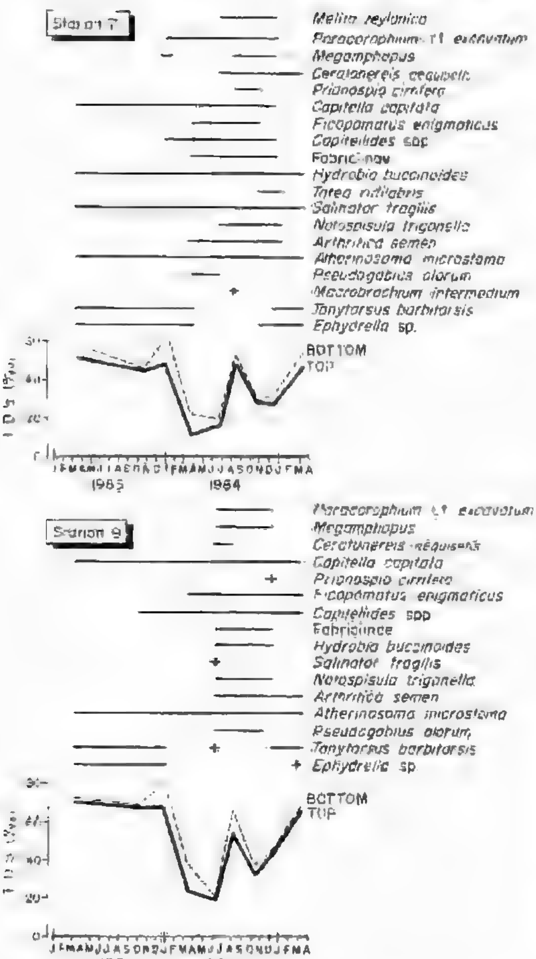



Fig. 3. Surface and bottom salinities (TDS ‰) and the occurrence of macroinvertebrates and fish at Stations 7 and 9 in the North Lagoon from March 1983 to March 1985.

*Tanytarsus barbitarsis* was easily the dominant littoral and benthic animal and it occurred throughout the South Lagoon on most occasions although with high salinities in March 1984 (Fig. 4) and March and April 1985 (Fig. 4) it did not occur at Stations 6S or 7S. At Stations 2S to 5S the abundance of *T. barbitarsis* was seasonal with highest numbers in summer (D. Paton pers. comm.).

Six fish species were collected in the North Lagoon (Table 1). The small mouthed hardyhead, *Atherinosoma microstoma*, and the blue spot goby, *Pseudogobius olorum*, were the ones most commonly collected by hand net. *A. microstoma* was distributed throughout the North Lagoon while *P. olorum* was restricted to more northerly areas until mid 1984 when salinities fell (Fig. 3). The other four species were collected only occasionally.

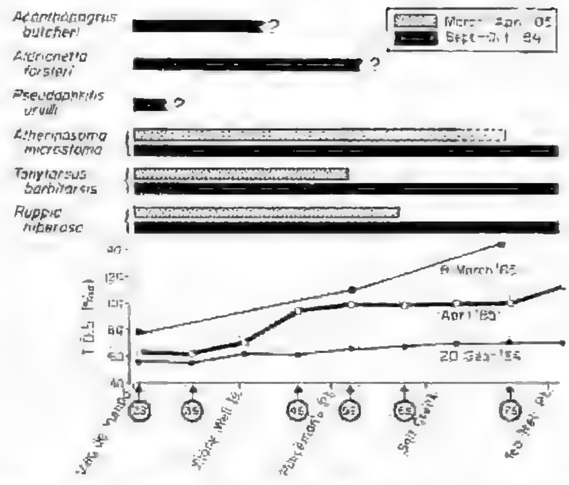



Fig. 4. Longitudinal salinity profiles and the distribution of biota in the South Lagoon during a low salinity period in spring (September–October) 1984 and a high salinity period in autumn (March–April) 1985.

A much more complete fish sampling program was conducted in the North Lagoon of the Coorong during 1984 by David Hall of the S. Aust. Dept of Fisheries. The common species in his catches, along with those in the present study comprise a complete list of the common fish occurring in the Coorong in 1984 (Table 2). They include freshwater species presumably washed in with the River Murray flow, marine species that use the Coorong as a nursery-growing area, and species that generally complete their life cycles in the estuarine-lagoonal system.

The hardyhead, *A. microstoma*, was the only fish that persisted in the South Lagoon. Hardyheads occurred in large numbers throughout the South Lagoon in winter, spring and early summer. Increasing salinities in late summer and autumn restricted their southerly distribution so that only a few specimens were collected at Station 7S in March 1985 when the salinity was 149‰, and they were still rare in April 1985 when the salinity had fallen to 100‰ (Fig. 4). In late winter and spring 1984 when salinities fell as low as 55‰, congolli (*Pseudaphritis urvilli*), black bream (*Acanthopagrus butcheri*) and yellow-eye mullet (*Aldrichetta forsteri*) also occurred in the South Lagoon (Fig. 4). Yellow-eye mullet and black bream were caught by professional fishermen in the northern section of the South Lagoon in August, September and October 1984 and recreational catches of mullet were recorded as far south as Salt Creek (D. Hall pers. comm.). No catches of congolli, black bream or yellow-eye mullet were recorded in July or November when TDS was around or above 70‰.

## Discussion

The high River Murray outflows from July–November 1983 had little immediate impact on the salinities in the North and South Lagoons. In December 1983 salinities were as high as 60‰ at the south end of the North Lagoon and above 80‰ in the South Lagoon. The major drop in salinities in the North Lagoon occurred between December 1983 and March 1984, resulting in salinities below 30‰ throughout the lagoon. During this period outflows from the barrages were moderate. Thus mixing of fresh water southwards in the Coorong is not simply controlled by River Murray flow but other factors such as sea levels, lagoon levels, wind direction and evaporation are probably involved (Noye 1975). Freshening of the South Lagoon occurred in the latter half of 1984 so that in September–October salinities were 50–70‰. These salinities were still well above those recorded in November 1975 (30–40‰) following a period of very heavy River Murray flow in 1973 and up to 1975 (Geddes & Butler 1984).

The River Murray flow produced significant effects upon the *Ruppia* populations in 1983 and 1984. In the North Lagoon, *Ruppia megacarpa*, a species which usually reproduces vegetatively and sets little seed (Brock 1982), flowered profusely in October 1983 after the first heavy outflows from the River Murray and the slight fall in salinity. In the South Lagoon, *Ruppia tuberosa* became abundant in 1984 and thick and extensive beds of flowering plants were observed in October–December 1984. This followed a drop in salinity to 55–70‰ along the South Lagoon in September 1984. This abundance of *R. tuberosa* contrasted with its scarcity during 1982, when salinities were generally above 90‰ (Geddes & Butler 1984), and supports observations made by others (Delroy *et al.* 1965[1]; Womersley 1975; Paton 1982[2]) that growth of *R. tuberosa* is inhibited at salinities above twice seawater.

The minor dilution of the North Lagoon during 1983 did not produce any changes in the distribution of macroinvertebrates. However, with the marked salinity fall in March 1984, most species extended their distributions southwards although there was a lag period with most species not occurring at the most southerly station until June.

No members of the estuarine-lagoonal macroinvertebrate fauna were collected in the South Lagoon although salinities there were within their tolerance limits in September–October 1984. Presumably longer periods at moderate salinity are necessary for the establishment of the estuarine-lagoonal fauna in the South Lagoon. The "salt lake" association of dipterans, ostracods, *Haloniscus searlei* and *Atherinosoma microstoma* persisted in the South Lagoon throughout 1983 and 1984.

The more estuarine conditions in 1983–84 did not see any significant increase in the number of species of macroinvertebrates in the North Lagoon. Only one further polychaete, *Prionospio cirrifera*, and one further gastropod, *Tatea rufilabris*, were collected. *Prionospio* sp. is a commonly encountered polychaete in the Leschenault and Peel-Harvey estuaries in south-western Australia (E. P. Hodgkin pers. comm.) and *Prionospio cirrifera* is common in many estuaries on the south east Australian coast, especially where there is considerable freshwater input or eutrophication (Rainer & Fitzhardinge 1981; Collett *et al.* 1984). *Tatea rufilabris* is a hydrobiid found in southern Australian estuaries (Ponder pers. comm.). Thus, even during periods of River Murray flow and moderate salinities, the number of species in the Coorong (23 species of macroinvertebrates) was much lower than those recorded in some other Australian estuaries (Rainer & Fitzhardinge 1981; Geddes & Butler 1984).

River Murray flow and the changed salinity pattern brought about changes in the fish fauna and the distributions of particular species. The freshwater species, *Cyprinus carpio*, *Nematalosa erebi* and *Philypnodon grandiceps*, occurred in the North Lagoon along with the marine and estuarine fish. The three freshwater species presumably were washed in with the River Murray flow, but large populations of *N. erebi* persisted along the entire length of the North Lagoon for considerable periods in 1983–84. Three species previously restricted to the North Lagoon, *Pseudaphritis urvilli*, *Acanthopagrus butcheri*, and *Aldrichetta forsteri*, entered the South Lagoon for a brief period in August–October 1984 when salinities were below 70‰. The distributions of these commercial fishes seem to respond rapidly to the establishment of favourable salinities, although catch per unit effort data suggest that only small numbers of fish were present (D. Hall pers. comm.).

The fish fauna of the Coorong, like that of the invertebrates, is very restricted compared to that in other estuaries (Pollard 1984). This is mostly due to the minor representation of marine fish in the Coorong. Of the 17 common species (Table 2), only five are marine species that use the Coorong

[1] Delory, L. B., Macrow, P. M. & Sorrell, J. B. (1965) The food of waterfowl (Anadidae) in salt water habitats of South Australia. Unpublished report of Fisheries and Fauna Conservation Department of South Australia.

[2] Paton, P. (1982) Biota of the Coorong. South Australian Department of Environment and Planning, Nov. 1982. S.A.D.E.P. 55 (unpublished).

TABLE 2. *Common fish in the North Lagoon of the Coorong during 1984. Species are grouped according to their habitat as follows: estuarine — can complete lifecycle in the Coorong; marine — generally reproduce at sea; freshwater — generally reproduce in fresh water.*

| Family | Species name | Common name |
|---|---|---|
| ESTUARINE | | |
| Atherinidae | [1] *Atherinosoma microstoma* (Günther)* | Small mouthed hardyhead |
| Gobiidae | *Pseudogobius olorum* (Sauvage) | Blue-spot goby |
| | *Arenogobius bifrenatus* (Kner) | Bridled goby |
| | *Callogobius mucosus* (Günther) | Sculptured goby |
| Bovichyidae | [1] *Pseudophritis urvilli* (Valenciennes)* | Congolli |
| Sparidae | *Acanthopagrus butcheri* (Munro) | Black bream |
| Bothidae | *Rhombosolea tapirina* (Günther) | Greenback flounder |
| Hemiramphidae | *Hyporhamphus regularus* (Günther) | River garfish |
| Engraulidae | [2] *Engraulis australis* (Shaw) | Southern anchovy |
| MARINE | | |
| Sciaenidae | *Argyosomus hololepidotus* (Lacépède) | Mulloway |
| Mugilidae | *Aldrichetta forsteri* (Valenciennes) | Yellow-eye mullet |
| Clupeidae | [3] *Sardinops neopilchardus* (Steindachner) | Australian pilchard |
| Galaxiidae | [4] *Galaxias maculatus* (Jenyns) | Common galaxias |
| FRESHWATER | | |
| Clupeidae | *Nematalosa erebi* (Günther) | Bony bream |
| Eleotridae | *Philypnodon grandiceps* (Krefft) | Big-headed gudgeon |
| Cyprinidae | *Cyprinus carpio* (Linneaus) | European carp |

[1] These species can breed in fresh water (Lloyd unpublished).
[2] Breeds in estuaries as far as is known.
[3] Breeds at sea as far as is known.
[4] Breeds in estuaries but larvae then spend time at sea before returning to estuary of fresh water (Pollard 1971).

lagoons as a nursery-growing area, while there are perhaps nine species that are resident within the system. A similar, but not so severe, restriction of usage by marine species has been noted for the Peel-Harvey system (Potter *et al.* 1983) and the Swan-Avon estuary (Prince & Potter 1983) in Western Australia. These authors suggest that the presence of a narrow channel and of extensive peripheral bays within the estuaries, make these systems conducive to an estuarine mode of life. Conversely these same factors make it difficult for marine fish to move in and out of the estuaries. The extreme salinity fluctuations in the Coorong may also limit fish diversity.

Hypersalinity can be a major factor limiting fish distribution within estuarine-lagoonal systems. Only six fish species occurred in Hamelin Pool, the hypersaline (~54‰) region of Shark Bay (Lenanton 1977), and while most species in South African estuaries-lagoons could tolerate salinities up to 55‰, only a few could tolerate salinities up to 70‰ (Hill 1981). A similar dimunition of fish fauna between 55 and 70‰ appears to occur in the Coorong. The most tolerant species in the Shark Bay and South African studies included members of the Atherinidae, the Mugilidae and the Sparidae, families which also include the most salt tolerant species in the Coorong. Considering the effects of salinity on the distributions of fishes within the Coorong, it appears that under the present hydrological and salinity regimes the fish faunas will sometimes be restricted in the southern end of the North Lagoon and on most occasions only the highly tolerant *Atherinosoma microstoma* will occur in the South Lagoon.

The effects of the River Murray flow of 1983–84 on salinity patterns and the distribution of biota in the Coorong were short-lived. Following the barrage closure in December 1984, salinities quickly rose to 36–70‰ in the North Lagoon and 80–140‰ in the South Lagoon by March 1985. This is an almost identical salinity pattern to that of March 1983 after a period of extended barrage closure. It seems that consistently high River Murray flows are needed to maintain an estuarine-marine situation in the North Lagoon and moderately hypermarine conditions in the South Lagoon of the Coorong.

**Acknowledgments**

Thanks to Helen Vanderwoude, David Paton, Greg Powell and Julie Francis for help in the field and the laboratory and the following people for identifying specimens; Pat Hutchings (polychaetes), Jerry Barnard (amphipods), Winston Ponder (gastropods) and Lance Lloyd and David Hall (fish). David Paton and David Hall also allowed access to unpublished data. The Engineering and Water Supply Department provided unpublished data on outflow from the River Murray Barrages and the South Australian Fisheries Department provided data on fish species and distribution. Thanks to Sandra Lawson for typing the manuscript, to Ruth Evans for the artwork and to the Zoology Department, University of Adelaide for support.

**References**

BROCK, M. A. (1982) Biology of the salinity tolerant genus *Ruppia* L. in saline lakes in South Australia. II. Population ecology and reproductive biology. *Aquat. Bot.* **13**, 249-268.

COLLETT, L. C., HUTCHINGS, P. A., GIBBS, P. J. & COLLINS, A. J. (1984) A comparative study of the macro-benthic fauna of *Posidonia australis* seagrass meadows in New South Wales. *Aquat. Bot.* **18**, 111-134.

GEDDES, M. C. (1984) Limnology of Lake Alexandrina, River Murray, South Australia, and the effects of nutrients and light on the phytoplankton. *Aust. J. Mar. Freshwat. Res.* **35**, 399-415.

——— & BUTLER, A. J. (1984) Physicochemical and biological studies on the Coorong lagoons, South Australia, and the effect of salinity on the distribution of the macrobenthos. *Trans. R. Soc. S. Aust.* **108**, 51-62.

HILL, B. J. (1981) Adaptations to temperature and salinity stress in South African estuaries. Ch. 11, pp. 187-197. *In* J. H. Day (Ed.) "Estuarine Ecology". (Balkema, Rotterdam).

HUTCHINGS, P. A. & GLASBY, C. J. (1985) Additional nereidids (Polychaeta) from eastern Australia, together with a redescription of *Namanereis quadraticeps* (Gay) and the synonymising of *Ceratonereis pseudoerythraeensis* Hutchings & Turvey with *C. aequisetis* (Augener). *Rec. Aust. Mus.* **37**(2), 101-110.

KANGAS, M. I. & GEDDES, M. C. (1984) The effects of salinity on the distribution of amphipods in the Coorong, South Australia, in relation to their salinity tolerance. *Trans. R. Soc. S. Aust.* **108**, 139-145.

LENANTON, R. C. J. (1977) Fishes from the hypersaline waters of the stromatolite zone of Shark Bay, Western Australia. *Copeia* (1977), 387-390.

NOYE, B. J. (1975) The Coorong. Publ. No. 39, 131 pp. (Department of Adult Education, University of Adelaide).

POLLARD, D. A. (1971) The biology of a landlocked form of the normally catadromous salmoniform fish *Galaxias maculatus*. I. Life cycle and origin. *Aust. J. Mar. Freshwat. Res.* **22**, 91-123.

——— (1984) A review of ecological studies on sea-grass fish communities, with particular reference to recent studies in Australia. *Aquat. Bot.* **18**, 3-42.

POTTER, I. C., LONERAGAN, N. R., LENANTON, R. C. J., CHRYSTAL, P. J. & GRANT, C. J. (1983) Abundance, distribution and age structure of fish populations in a Western Australian estuary. *J. Zool. Lond.* **200**, 21-50.

PRINCE, J. D. & POTTER, I. C. (1983) Life-cycle duration, growth and spawning times of five species of Atherinidae (Teleostei) found in a Western Australian estuary. *Aust. J. Mar. Freshwat. Res.* **34**, 287-301.

RAINER, S. & FITZHARDINGE, R. C. (1981) Benthic communities in an estuary with periodic deoxygenation. *Ibid.* **32**, 277-343.

WOMERSLEY, H. B. S. (1975) The plants. Ch. 7. *In* J. Noye (Ed.) "The Coorong". Publ. No. 39 (Department of Adult Education, University of Adelaide).

# SALINA BED INSTABILITY AND GEODETIC STUDIES AT LAKE EYRE, SOUTH AUSTRALIA

by J. A. DULHUNTY*

## Summary

DULHUNTY, J. A. (1987) Salina bed instability and geodetic studies at Lake Eyre, South Australia. *Trans. R. Soc. S. Aust.* 111(4), 183-188, 30 November, 1987.

Horizontal compressional forces in saltcrusts of Lake Eyre cause fracturing with overthrusting in thin crusts of marginal areas, and warping or buckling in central areas where crusts are thicker and stronger. Unconsolidated Holocene sediments adjust by deformation to warping of overlying saltcrusts and the true equilibrium level of the lakebed surface is elevated or depressed. When the lake is filled saltcrusts are dissolved and deforming pressures are released, allowing the surface of the sediments to return towards equilibrium level under gravity. Claims that any one place, in any one bay, is the lowest place in Australia, are doubtful. A more appropriate concept may be that the lowest landsurfaces on the Australian continent are in the southern bays of Lake Eyre North.

KEY WORDS: Lake Eyre, saltcrusts, lateral forces, overthrusting, warping.

## Introduction

Lake Eyre is a large arid ephemeral terminal lake (Johns 1955; Bonython 1955, 1956; Dulhunty R. 1975, 1984, 1986; Dulhunty J. A. 1977, 1978, 1982; Allan *et al.* 1986; Callen & Wells 1986). It is the sump of an internal drainage basin, consisting mostly of semiarid and arid country covering almost one sixth of the Australian continent. River courses draining the Lake Eyre Basin seldom carry flowing water as far as the lake, as it is mostly lost to evaporation in desert country of low relief through which it must pass. Small amounts of water which do reach the lake, at intervals of 2 to 3 years, cover only parts of the bed and usually dry up in less than one year. Infrequent major fillings, once in 25 to 50 years, cover the whole of the bed to depths of 5 to 10 m, and may require 4 to 6 years to dry up (Bye *et al.* 1978; Dulhuntry R. 1984; Allan 1985).

Lake Eyre lies in the most arid region of Australia, with an average annual rainfall of less than 127 mm, maximum summer temperatures up to 61°C (Price 1955), and an annual evaporation rate of about 2.5 m (Bonython 1955; Penman 1955).

The purpose of this paper is to record evidence of lakebed instability or warping of saltcrusts and deformation of Holocene sediments in the salina area of Lake Eyre North, and its significance in geodetic studies and the concept of the lowest place on the Australian continent.

## Saltcrusts

Saltcrusts up to about 50 cm in thickness occur in the three southern bays of Lake Eyre North, where final evaporation of brines takes place. The salt has been transported into Lake Eyre, dissolved in riverwater and groundwater, after the lake became terminal following the onset of late Pleistocene aridity which has persisted through Holocene to the present day (Bowler 1978; Dulhunty J. A. 1982). When sufficient water enters the salina area during major fillings, pre-existing saltcrusts are dissolved; new sediments are deposited, and finally, with evaporation of water, salt is reformed into new crusts (Dulhunty J. A. 1982).

Three generations of saltcrusts have been recorded at Lake Eyre. The first occurred prior to the 1949-50 filling (Madigan 1930); the second occurred between the 1949-50 and 1974 fillings (Dulhunty J. A. 1974; Dulhunty R. 1975; Bonython 1956; Johns 1963), and the third formed after the water of the 1974 filling dried up in about 1979 (Dulhunty R. 1984). In addition to the three recorded crusts, a long series of prehistoric saltcrusts of gradually increasing volume, must have existed between major fillings in late Pleistocene and Holocene times.

In 1972 a survey of saltcrust thicknesses was carried out by Dulhunty over Madigan Gulf and Jackboot and Belt Bays. The publication of results (Dulhunty J. A. 1974) included records of crust thicknesses measured previously in Madigan Gulf by Madigan (1930); Bonython (1956), and the South Australian Geological Survey (Johns 1963). Differences in salt thicknesses measured at different times, in the same places in Madigan Gulf, were also recorded and discussed.

Levelling surveys of the lakebed surface at the base of the saltcrust in Madigan Gulf were made in 1954 by Bonython (1956); in 1969 by the South

* Department of Geology and Geophysics, University of Sydney, N.S.W. 2006.